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SUMMARY OF ENVIRONMENTAL ACOUSTIC DATA PROCESSING

Glen E. Ellis

Texas University at Austin

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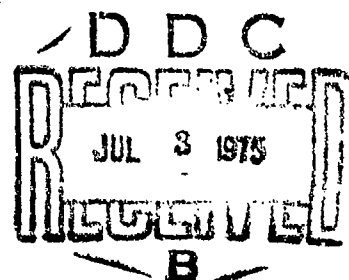
THE UNIVERSITY OF TEXAS AT AUSTIN

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SUMMARY OF ENVIRONMENTAL ACOUSTIC DATA PROCESSING
Final Report under Contract N00014-70-A-0166, Task 0019
1 September - 31 December 1973

Glen E. Ellis

OFFICE OF NAVAL RESEARCH
Contract N00014-70-A-0166, Task 0019
NR 292-131

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report summarizes the tasks performed under Contract N00014-70-A-0166, Task 0019, during the period 1 September through 31 December 1973. Descriptions of the continuous wave (cw), ambient noise, and explosive source (SUS) processing systems developed and implemented are provided. The utilization of these processing systems for the "quick-look" analyses and volume data processing for the CHURCH GABBRO Exercise is described. (U)

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Final Report under Contract N00014-70-A-0166, Task 0019
1 September - 31 December 1973

Glen E. Ellis

APPLIED RESEARCH LABORATORIES

THE UNIVERSITY OF TEXAS AT AUSTIN

AUSTIN, TEXAS 78712

ABSTRACT

This report summarizes the tasks performed under Contract
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processing systems developed and implemented are provided.
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"quick-look" analyses and volume data processing for the
CHURCH GABBRO Exercise is described.

TABLE OF CONTENTS

I. INTRODUCTION

The work performed under Contract N00014-70-A-0166, Task 0019, covered the period from 1 September through 31 December 1973. The tasks performed included the implementation of hardware/software systems to process environmental acoustic data recorded with ACODAC systems, participation in the preparation of Data Analysis Plans for the CHURCH ANCHOR and SQUARE DEAL Exercises, "quick-look" analyses, volume data processing of the SUS data for the CHURCH GABBRO Exercise, and data processing in support of the Chief Scientist in the BLAKE Test.

II. DATA PROCESSING SYSTEMS

A. General Hardware/Software Systems

The data processing systems implemented for the ACODAC data were constructed around the CDC 3200 computer system installed at Applied Research Laboratories (ARL), The University of Texas at Austin, in late 1965. Figure 1 shows the configuration and data paths of the CDC 3200 digital computer system. This general purpose computer system, while serving as a general laboratory facility, has been heavily utilized in signal physics studies sponsored by the Naval Ship Systems Command (now Naval Sea Systems Command). The analog-to-digital conversion peripheral was constructed to handle large volumes of active sona· data on a routine basis for these studies.

Since the installation of the CDC 3200 computer system in 1965, an extensive software library exceeding 700 application routines has been developed. Due to the nature of the majority of work conducted at ARL, special emphasis has been placed on the development of applications software for acoustics and signal processing.

B. Continuous Wave (cw) Processing System

The ARL continuous wave measurement system is a hardware/software configuration designed to perform narrowband analysis over the frequency range of 10 to 110 Hz. The primary source of data collection for the current analyses is the ACODAC receiving array. The data processing system is divided into five tasks: data conversion, signal estimation, noise estimation, calibration, and display. The final products are plots of propagation loss and signal excess.
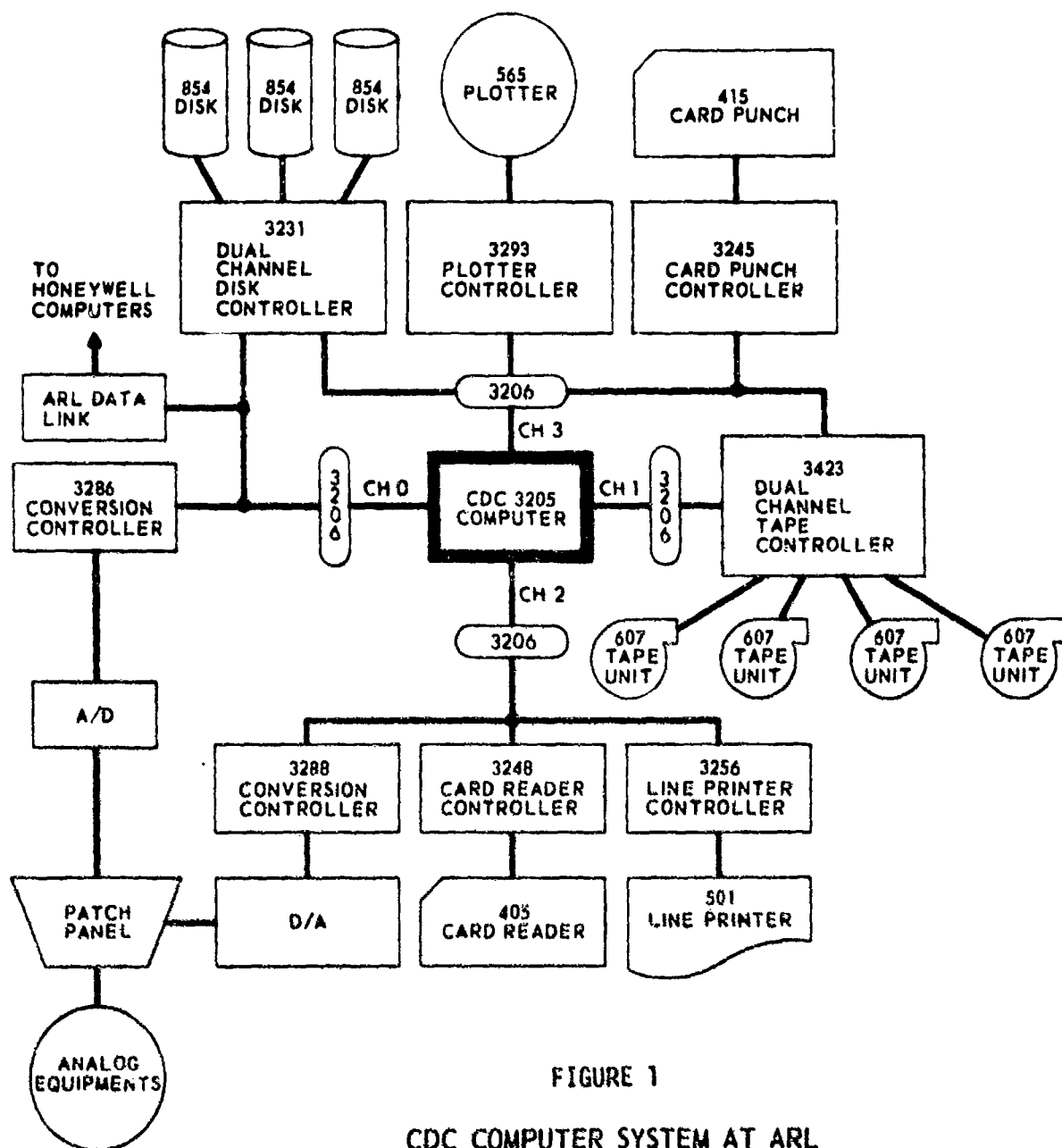
FIGURE 1

CDC COMPUTER SYSTEM AT ARL

1. Data Conversion

The first task performed by the processing system is the conversion of time series data to the frequency domain using a real-time analyzer (RTA) as the front end to the CDC 3200 digital computer (Fig. 2).

The ACODAC analog tape is played back at an 80:1 time compression. Analysis is performed on one data channel (hydrophone) on each pass of the analog tape. The analog data are filtered (5 to 120 Hz), amplified, and input to the RTA, making use of the full dynamic range of the analyzer. Simultaneously, the ACODAC timecode, gain state, and overload information are input to the digital computer (Fig. 2). The sampling sync (350 Hz) for the RTA is derived from the 50 Hz timecode carrier by multiplication with a phase lock frequency multiplier. Synchronization of the RTA to the analog tape allows compensation for the speed variations in tape recorder speed that can occur during recording, duplication, and playback. This sampling sync is also used by the RTA reset counter, which causes the real-time analyzer to output a single frequency sweep each time its memory is filled. These sweeps cover contiguous blocks of data. The RTA reset counter is in turn synchronized to the beginning of each ACODAC minute by means of the P_R position marker in the timecode.

With an effective sample rate of 350 Hz, the RTA will sweep incrementally in 500 steps from 0 to 117 Hz at a rate of 18 2/3 times a second, each sweep covering 4 2/7 sec of ACODAC data. During each sweep, the linear step spectrum output of the analyzer is digitized and stored in the CDC 3200 computer. The data are also being constantly monitored by a hardware calibration and overload signal detector. Information regarding any such detections is also stored in the computer.

For each of the 14 sweeps generated during an ACODAC minute, the 500 spectral lines output by the RTA are tested for
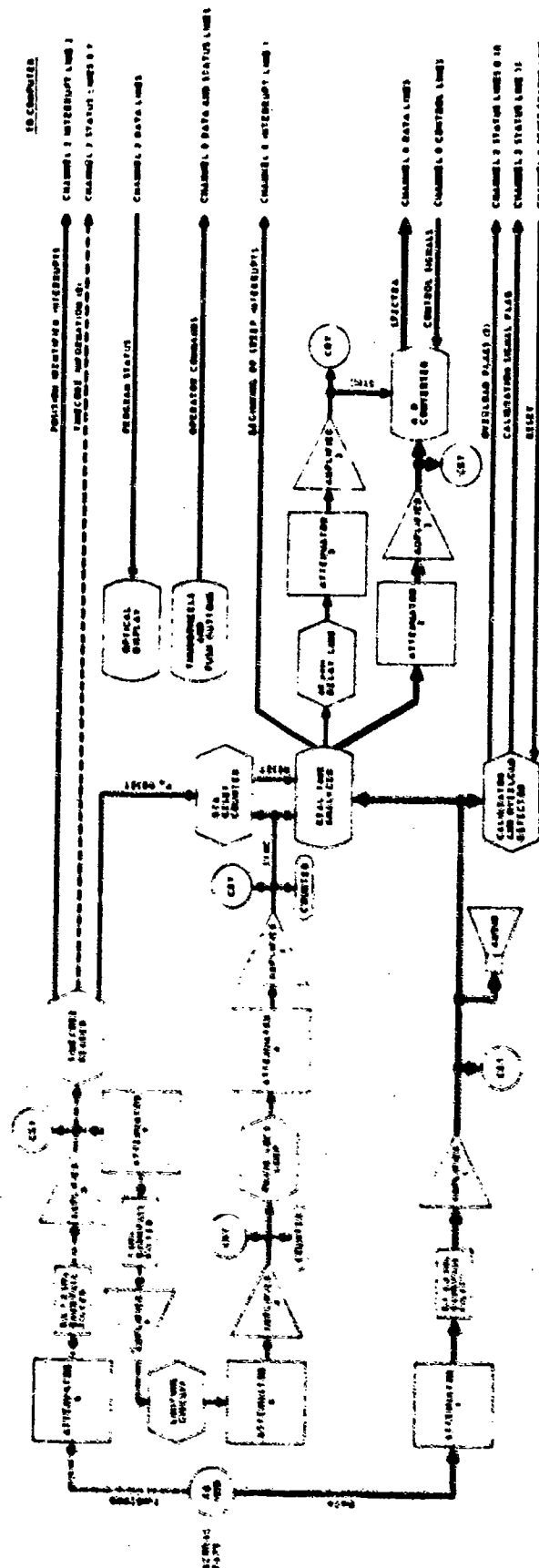
5

FIGURE 2

ANALOG EQUIPMENT CONFIGURATION FOR ANALYSIS OF ACODAC DATA VIA RTA

distortion due to a spectral output exceeding the maximum input amplitude range of the A/D converter. If the input range is exceeded, the process is aborted, and the operator is instructed to reduce the amplification of the spectral outputs before restarting the process at the place where the distortion began. Once this testing is completed, all 14 of the sweeps in each ACODAC minute are stored on digital tape. The computer constantly monitors the timecode data to ensure that the synchronization is maintained between the data and the timecode information.

2.   Noise Power Estimation

The purpose of the noise estimator is to obtain an accurate value for the noise power in the signal band. The data from the RTA are treated as power spectral density estimates. The signal band is taken to be the sum of squares of four lines from the RTA centered at the signal frequency, and the bandwidth is $4(0.233 \text{ Hz})=0.93 \text{ Hz}$. Two noise bands are taken to be 3 Hz (13 lines) wide, one on each side of the signal starting 1.5 Hz away from the signal. The noise in the signal band, when the signal is absent, and the noise in the side bands are all used in the noise estimator in the following way:

> n_L = average noise power of a single line in lower side band,
> n_s = average noise power of a single line in signal band when the signal is absent, and
> n_u = average noise power of a single line in the upper side band.

The averages are frequency averages. For example, the noise power in a side band is the sum of squares of 13 samples (lines) from the RTA divided by 13. The ratio of noise power in the signal band to noise power in the side band is

$$R = \frac{n_s}{n_L + n_u} \quad ,$$

7

and R is updated each time the signal is known to be absent.

When the signal is present the noise power in the signal band is estimated by using the upper and lower noise bands and the ratio R,

$\hat{n}_L$ = measured noise power per line in lower side band when signal is present,

$\hat{n}_u$ = measured noise power per line in upper side band when signal is present, and

$\hat{n}_s = 4R(\hat{n}_L+\hat{n}_u)$, estimated noise power in signal band.
The caret is used to denote when the signal is present and it is deleted when the signal is absent.

The advantage of this procedure is that a good estimate of the noise power $\hat{n}_s$ is obtained even when the side band noise power is asymetrical about the signal. An example of asymetry would be the presence of shipping lines in the noise side bands. It is assumed that there is a linear relation between the noise in the side bands and the signal band. It is also assumed that the noise is stationary while the signal is present.

3.   Signal Power Estimation

The signal power is estimated when the signal is present by summing the squares of the four lines in the signal band to give signal plus noise power s+n. The estimated noise power $\hat{n}_s$ is subtracted out to give the estimated signal power $\hat{s}=(s+n-\hat{n}_s)$.

4.   Calibration

Each ACODAC data tape contains a header which consists of a sequence of externally supplied calibration signals at known levels followed by a sequence of internally generated calibration signals.

8

The external calibration sequence consists of five frequencies
(12.5, 25, 50, 100, and 200 Hz), each of which were supplied at four
levels (-50, -40, -30, and -20 dB re 1 Vrms). For the lowest level,
-50 dB re 1 Vrms, the ACODAC amplifiers were in the highest of their
four gain states (40, 30, 20, and 10 dB), and they stepped through
the remaining states as the external signal level was increased.
These external calibration signals are used to measure overall
frequency response and amplifier gain state.

Header signals were recorded before each ACODAC deployment.
Changes in the frequency response of the ACODAC electronics could
occur after deplo   due to changes in the system's environment.
The internal calibration signals are used to correct for such changes.
These signals, supplied every 6 h, consist of two frequencies (50
and 200 Hz), supplied in parallel at four different levels sequentially.
As the internal calibration signal level changes sequentially, the
amplifiers step through their gain states. A final calibration
correction is to account for the -0.27 dB change in the output of
the calibration signal generator as a result of the ACODAC environ-
mental temperature change upon deployment.

The absolute levels of the external calibration signals,
the measured frequency responses, and the measured in-situ corrections
are then combined with the hydrophone sensitivities, resulting in a
set of calibration factors which are then applied to the data to yield
signal pressure in micropascals (μPa).

5. Display

The 14 calibrated 4 2/7 sec measurements of signal plus
noise and noise for each minute of signal reception are stored on
digital magnetic tape along with time, range, source depth, and
source level. Plots of propagation loss and signal excess are
generated from these tapes. Signal excess is the ratio of signal
plus noise power to noise power and it is displayed two different

9

ways. The plotted data show the signal excess in situ as it was processed through a 0.93 Hz filter. The tabulated data, which are range or time averaged, present a modified signal excess. The reason for the modification is to account for differences in source level, which changed during the exercise, and to adjust the processing bandwidth from 0.93 to 1.0 Hz. The tabulated data show the signal excess for a 200 dB source level for all events, frequencies, source depths, and for a processing bandwidth of 1.0 Hz.

6. Error Analysis

The primary sources of error causing bias in the estimation of propagation loss are:

   a.   source level,

   b.   hydrophone sensitivity, and

   c.   calibration level.

The secondary sources of error are in the record/reproduce system and data processing system. These are random errors, and they are primarily due to the mechanical problems of tape handling. For example, the internal 50 Hz calibration signal will vary 0.3 dB over a 10 sec interval, and a typical standard deviation for the 50 Hz calibration level is 0.1 dB. The cw data are processed through a RTA which has a measured linearity of 1 dB out of a 50 dB dynamic range. The linearity of the tape record/duplication/reproduce system is unknown.

In summary, the random errors due to mechanical systems are negligible because of the large averaging times in estimating calibration levels and estimating propagation loss.

C.   Ambient Noise Processing System

The ARL ambient noise measurement system (ANMS) is a hardware/software configuration designed to perform 1/3 octave band analysis

10

over the frequency range of 10 to 300 Hz. The primary source of
data collection for the current analyses is the ACODAC receiving
array. The processing system is divided into three tasks: data
conversion, calibration, and display.

1. Data Conversion

The first task performed by the analysis system is the
conversion of time series data to the frequency domain using a
real-time analyzer (RTA) as the front end to a digital computer
(Fig. 2). Figure 1 shows the configuration and data paths of the
CDC 3200 digital computer system.

The ACODAC analog tape is played back at a 20:1 time
compression. The analysis is performed on one data channel on each
pass of the analog tape. The analog data are filtered (5 to 300 Hz),
amplified, and input to the RTA, making use of the full dynamic range
of the analyzer. Simultaneously, the ACODAC timecode, gain state,
and overload information are input to the digital computer (Fig. 1).
The sample sync (900 Hz) for the RTA is derived from the 50 Hz time-
code carrier by multiplication with a phase lock frequency multiplier.
Synchronization of the RTA to the analog tape allows compensation for
the speed variations in tape recorder speed that can occur during
recording, duplication, and playback. This sampling sync is also
used by the RTA reset counter, which causes the real-time analyzer to
input a single frequency sweep each time its memory is filled. These
sweeps cover contiguous blocks of data. The RTA reset counter is in
turn synchronized to the beginning of each ACODAC minute by means of
the P_R position marker in the timecode.

With an effective sample rate of 900 Hz, the RTA will sweep
from 0 to 300 Hz 12 times a second, each sweep covering 1 2/3 sec of
ACODAC data. During each sweep, the linear step spectrum output of
the analyzer is digitized and stored in the CDC 3200 computer. The
data are also being constantly monitored by a hardware calibration

11

and overload signal detector. Information regarding any such detections is also stored in the computer.

To prevent distortion due to ACODAC gain changes and amplifier switching transients, those sweeps generated during the first and last 5 sec of each ACODAC minute are disregarded. The remaining 50 sec of each minute are divided into five 10 sec blocks. For each of the 6 sweeps generated during a 10 sec block, the 500 spectral lines output by the real-time analyzer are floated, squared, and tested for distortion due to a spectral output exceeding the maximum input amplitude range of the A/D converter (RTA). If the input range is exceeded, the process is aborted, and the operator is instructed to reduce the amplification of the spectral outputs before restarting the process at the place where the distortion began. Once this testing is completed, all 6 of the sweeps in each 10 sec block are averaged frequency line by frequency line; 1/3 octave bands are then formed by summing over the appropriate frequency lines. The data are then stored on digital tape in 10 sec averages. The computer constantly monitors the timecode data to ensure that synchronization is maintained between the data and the timecode information.

2. Calibration

Calibration for the Ambient Noise Processing System is identical to that described for the Continuous Wave Processing System in B.4. above.

However the absolute levels of the external calibration signals, the measured frequency responses, and the measured in situ corrections are combined with the hydrophone sensitivities and a bandwidth correction which normalizes each band to 1 Hz. The result is a set of calibration factors which are then applied to the data to yield noise intensities in $dB//\mu Pa/Hz^{1/2}$.

3. Display

The calibrated 10 sec averages are used to generate a histogram of noise intensity, standard plots of noise intensity versus time, and a tabulated version of noise intensity versus time.

4. Processing Error Analysis

The error bands for the noise intensity estimates were ±0.3 dB. This limit includes the effects of the playback recorder and the analysis system.

A crosscheck of the analysis system that includes the RTA was conducted during the analysis phase. The reference is a broadband (5 to 300 Hz) digitization and FFT processing system. The results from the reference system differ from the RTA system by approximately 0.1 dB.

D. Explosive Source (SUS) Processing System

The data generated by explosive sources (SUS) to study the propagation effects have consisted of data over the frequency range of 10 to 300 Hz and propagation ranges up to 2000 nm. The primary receiver for this processing system is the ACODAC.

The data volume from any one exercise is 10,000 to 40,000 hydrophone shots. The receiving systems (ACODAC) are suspended throughout the water column, with the data being recorded on long term (10 days) multichannel analog recorders. The large volume of data to be processed together with the short time period allocated for analysis required the implementation of an automatic SUS processing system.

ARL provided the implementation of an automatic SUS processor in a two month time period in conjunction with data reduction. The short start up period was made possible by using a currently existing

hardware/software system that was implemented for active sonar signal processing studies. The hardware utilized in the SUS processor consisted of a CDC 3200 digital computer with associated peripherals which include a sophisticated analog-to-digital and digital-to-analog interface. The software for the implentation of the SUS processing system was drawn from the existing signal processing software library (over 200 programs) and modified to handle the transient character of the source.

1. SUS Processor Description

The analog data recordings are time compressed in playback and converted to digital format along with associated timing and system information. Three data channels or hydrophones are converted simultaneously. The data are filtered in playback for antialiasing and antistrumming (low frequency receiver effects). The sampling rate, which is synchronized by a tone on the data tape to minimize analog record/playback variations, is determined by the frequency range of analysis. The broadband digitized signals are not achieved after the processing is completed.

The heart of the automatic SUS processor is a software system with an adaptive algorithm that determines the threshold for detection based on estimates of the ambient noise and the envelope of the SUS signal. Coincident detection can be required across multichannels to minimize the false alarm rate. For example, Fig. 3 shows the arrival of a shot received on the hydrophone data channels. Source information from the exercise operations is input to the processor which utilizes a simple propagation model to calculate an expected event arrival time window.

The SUS signal duration is independently fixed on each data channel since varying propagation paths can exist between the source and receiving hydrophones. The integration window is modified by visual inspection throughout a given source run as being necessary for proper energy estimation.

14
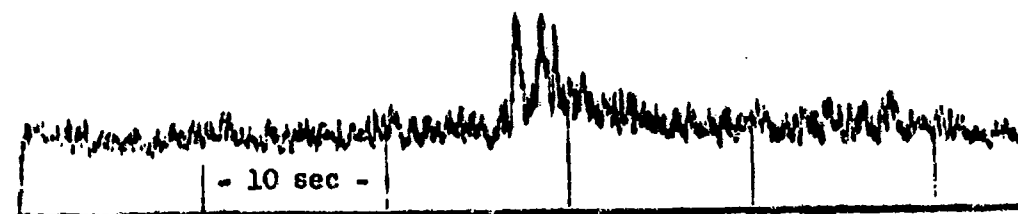
CHANNEL 1

CHANNEL 2

CHANNEL 3

FIGURE 3

SUS ARRIVAL ON THREE HYDROPHONE CHANNELS
(Signal envelope vs time)

15

Once the event is detected, an FFT algorithm is used to determine the high resolution spectrum of the signal plus noise. The resolution in the spectral estimation is based on the sampling rate chosen and a 4096 point transform. The spectrum of the ambient noise immediately preceding each SUS is determined in a like manner.

The structure of the received SUS frequency spectrum is determined by the multipath arrival structure and the SUS source character. For example, Fig. 4 shows the spectrum of two different SUS arrivals including the noise spectrum preceding each arrival. The spectra are remarkably different because of the source depth difference, which determines the SUS bubble pulse frequency.

The general flow of the shot processing is summarized in Fig. 5, and the parameters of the processor are outlined in Table I.

2. Processor Outputs

For each SUS signal detected the following information is output to digital tape and is used in the analysis of the acoustics of the environment:

1) SUS event time to 0.01 sec.

2) SUS duration to 0.01 sec.

3) High resolution spectra of signal plus noise.

4) High resolution spectra of the ambient noise sample associated with each SUS.

5) SUS signal energy, ambient noise energy, and signal-to-noise estimates in 1 and 1/3 octave frequency bands.

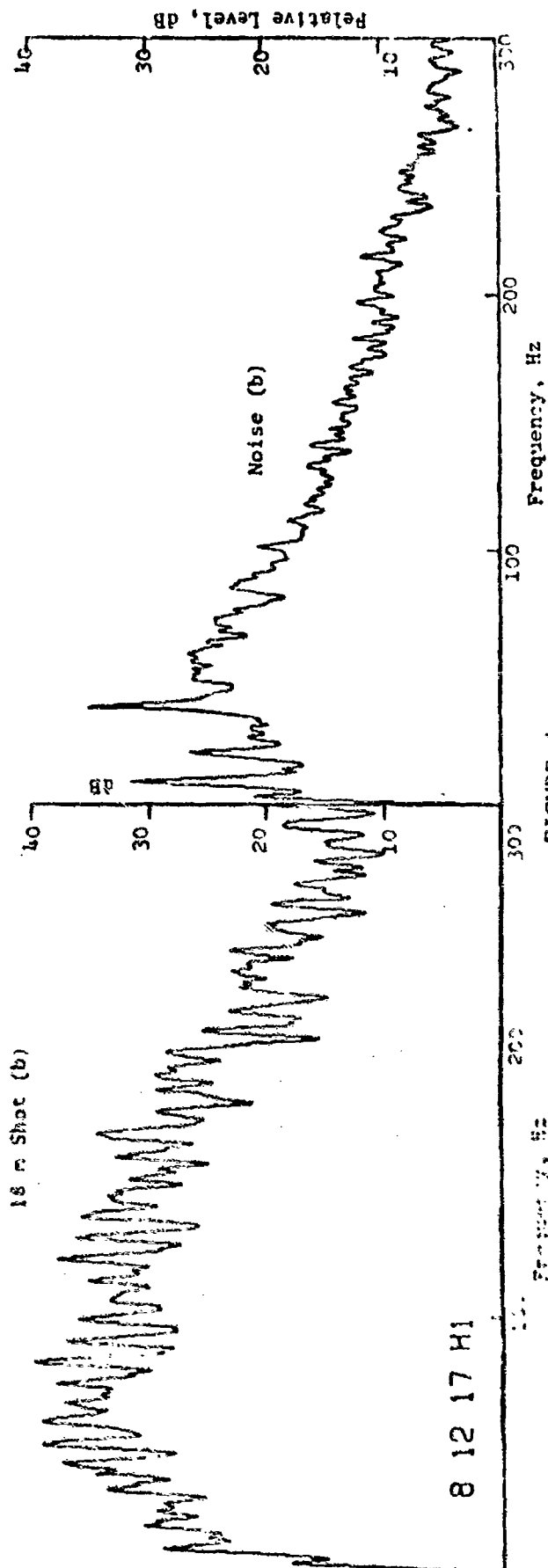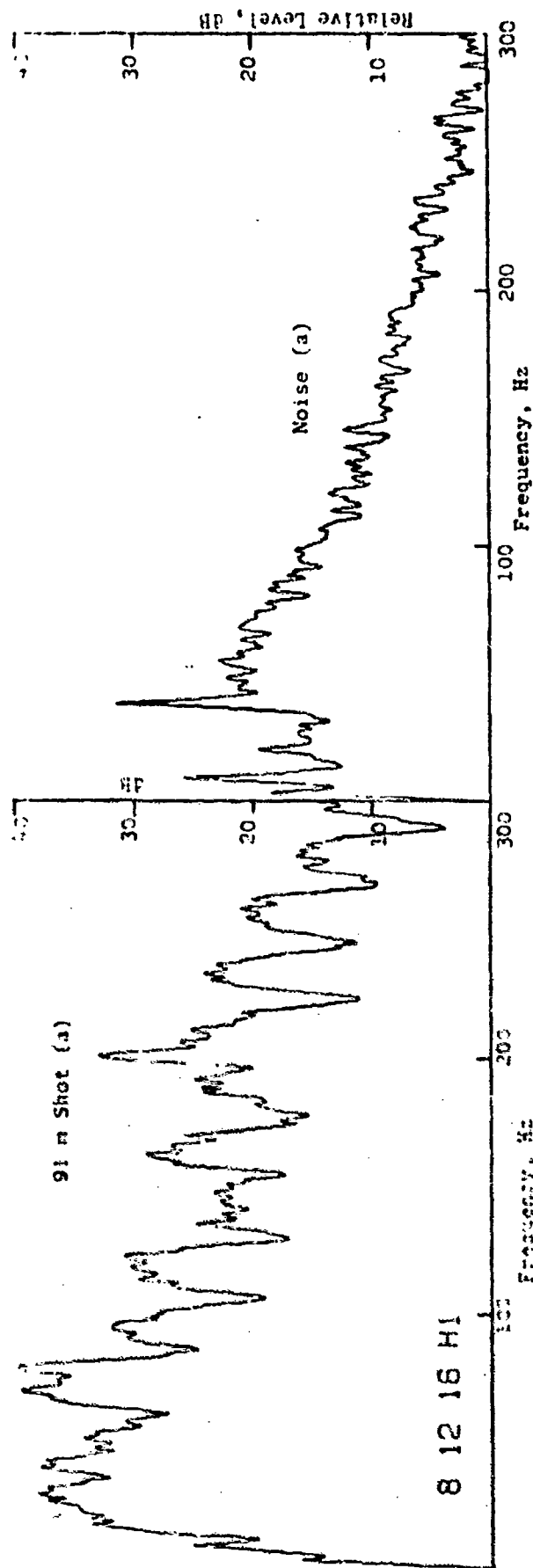6) Propagation loss and signal-to-noise estimates versus range and/or time.

16

FIGURE 4

POWER SPECTRA OF SUS
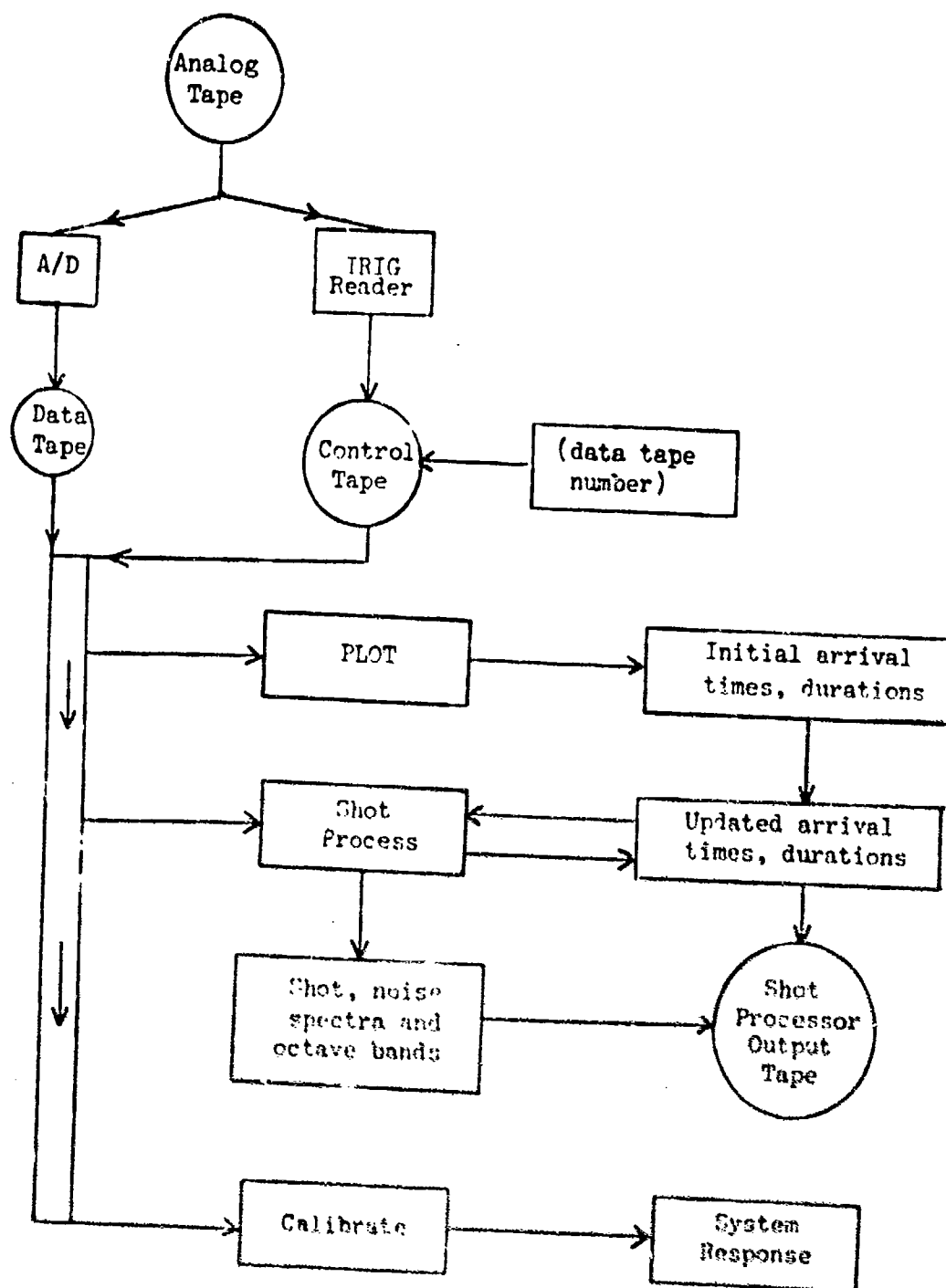SIGNALS AND AMBIENT NOISE

17

FIGURE 5

GENERAL FLOW OF SUS PROCESSING

TABLE I

ARL SUS PROCESSING SYSTEM

DATA SOURCE: ANALOG TAPE

PPOCESSING TECHNIQUE: ANALOG TO DIGITAL CONVERSION OF CONTINUOUS RECORD INTER-

    MEDIATE STORAGE ON DIGITAL TAPE AUTOMATIC COMPUTER EVENT DETECTION ADAPTIVE

    SIGNAL DURATION DETERMINE FFT ENERGY ANALYSIS. RANDOM ACCESS DISK FOR

    SIGNAL SORTING

SIMULTANEOUS PROCESSING OF THREE HYDROPHONE CHANNELS

PLAYBACK SPEEDUP: 20/1

PROCESSING SPEED: 10-15 SEC FOR HYDROPHONE SHOT INCLUDING NOISE (EXERCISE

    DEPENDENT)

RESOLUTION: EVENTS TO 0.01 SEC, FREQUENCY TO 0.15 Hz

AVAILABLE OUTPUTS:

    SIGNAL ARRIVAL TIMES

    SIGNAL DURATION

    POWER SPECTRA FOR SIGNAL AND NOISE

    OCTAVE BAND ENERGIES

    PROPAGATION LOSS

    SIGNAL-TO-NOISE RATIOS

III. DATA PROCESSING

The data processing and reduction of environmental acoustic measurements to descriptors of the ocean acoustics consist of planning, several quick-look or quick-response analyses, and volume data processing for the CHURCH GABBRO Exercise.

A. Data Processing Planning

ARL participated in the preparation of the CHURCH ANCHOR and SQUARE DEAL Data Analysis Plans. These plans provided the interactions between participants and the data flow necessary to achieve the exercise goals. ARL attended numerous meetings during this preparation phase. The response of ARL to the tasking outlined in these plans was to the LRAPP Manager via memoranda.

B. Quick-Look Analyses

The initial quick-look or quick-response analysis was conducted on ACODAC data from the CHURCH GABBRO Exercise. This analysis demonstrated the data processing capability at ARL and indicated the type of resolution that could be applied to such data analyses.

The VIBROSEIS cw source was deployed during the CHURCH GABBRO Exercise. A quick-response analysis was performed by examining the narrowband spectra for harmonic distortion and level. The analysis was reported to the LRAPP Manager in memorandum form.

C. Volume Data Processing

SUS data from the CHURCH GABBRO Exercise were processed for estimates of propagation loss and signal-to-noise. The data were recorded with ACODAC receivers. Approximately 13,000 hydrophone shots were processed for 1/5 octave frequency bands. The results of this data reduction were forwarded to the Chief Scientist for interpretation and reporting.

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Report Number	Personal Author	Title	Publication Source (Originator)	Pub. Date	Current Availability	Class.
55	Weinstein, M. S., et al.	SUS QUALITY ASSESSMENT, SQUARE DEAL	Undersea Systems, Inc.	750207	ADA007559; ND	U
BKD2380	Unavailable	WESTLANT 74 PHASE 1 DATA SUMMARY (U)	B-K Dyanmics, Inc.	750301	NS; ND	U
TM-SA23-C44-75	Wilcox, J. D.	MOTION MODEL VALIDATION FROM LRAPP ATLANTIC TEST BED DATA	Naval Underwater Systems Center	750317	ND	U
RAFF7412; 74-482	Scheu, J. E.	SQUARE DEAL SHIPPING DENSITIES (U)	Raff Associates, Inc.	750401	ADC003198; NS; ND	U
PSI TR-004018	Barnes, A. E., et al.	ON THE ESTIMATION OF SHIPPING DENSITIES FROM OBSERVED DATA	Planning Systems Inc.	750401	AD C9L56L ND	U
NUSC TD No.4937	LaPlante, R. F., et al.	THE MOORED ACOUSTIC BUOY SYSTEM (MABS)	Naval Underwater Systems Center	750404	ADB003783; ND	U
USI 460-1-75	Weinstein, M. S., et al.	SUS SIGNAL DATA PROCESSING (U) INVESTIGATIONS CONDUCTED UNDER THE DIAGNOSTIC PLAN FOR CHURCH ANCHOR AND SQUARE DEAL SHOT DATA (U)	Underwater Systems, Inc.	750414	ADC002353; ND	U
Unavailable	Ellis, G. E.	SUMMARY OF ENVIRONMENTAL ACOUSTIC DATA PROCESSING	University of Texas, Applied Research Laboratories	750618	ADA011836	U
Unavailable	Edelblute, D. J.	OCEANOGRAPHIC MEASUREMENT SYSTEM TEST AT SANTA CRUZ ACOUSTIC RANGE FACILITY (SCARF)	Lockheed Missiles and Space Co., Inc.	751015	ADB007190	U
Unavailable	Unavailable	SUS SOURCE LEVEL COMMITTEE REPORT	Underwater Systems, Inc.	751105	ADA019469	U
Unavailable	Hampton, L. D.	ACOUSTIC BOTTOM INTERACTION EXPERIMENT DESCRIPTION	University of Texas, Applied Research Laboratories	760102	ADA021330	U
PSI-TR-036030	Turk, L. A., et al.	CHURCH ANCHOR: AREA ASSESSMENT FOR TOWED ARRAYS (U)	Planning Systems Inc.	760301	ND	U
NUC TP 419	Wagstaff, R. A., et al.	HORIZONTAL DIRECTIONALITY OF AMBIENT SEA NOISE IN THE NORTH PACIFIC OCEAN (U)	Naval Undersea Center	760501	ADC007023; NS; ND	U
NRL-MR-3316	Young, A. M., et al.	AN ACOUSTIC MONITORING SYSTEMS FOR THE VIBROSEIS LOW-FREQUENCY UNDERWATER ACOUSTIC SOURCE	Naval Research Laboratory	760601	ADA028239; ND	U
ARL-TR-75-32	Ellis, G. E.	SUMMARY OF ENVIRONMENTAL ACOUSTIC DATA PROCESSING	University of Texas, Applied Research Laboratories	760705	ADA028084; ND	U
Unavailable	Unavailable	SUMMARY OF ENVIRONMENTAL ACOUSTIC DATA PROCESSING	University of Texas, Computer Science Division	761013	ADA032562	U
TTA83676285	Unavailable	ANALYSIS PLAN FOR NARROWBAND/NARROWBEAM AMBIENT NOISE (U)	Tetra Tech, Inc.	761112	ADC008275; NS; ND	U
USI 564-1-77	Wallace, W. E., et al.	REPORT OF CW WORKSHOP. NORDA, BAY ST. LOUIS, MISS., 28-29 SEPT 1976	Underwater Systems, Inc.	770124	ND	U

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